Reef Fish Habitat, Faunal Assemblages, and Factors Determining Distributions in the South Atlantic Bight[1]

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RESUMEN

Existen importantes pesquerías comerciales y deportivas de peces de arrecife (coros) en la Cuenca del Atlántico Sur, y las especies más buscadas son las chernas (Serranidae) y los pargos (Lutjanidae). Para la ejecución correcta de esta pesquería, se necesita el conocimiento de la extension del habitat de arrecifes y la ecología de las especies.

Amplias investigaciones de los recursos en la Cuenca del Atlántico Sur, durante 30 anos, han demostrado lo siguiente: (1) que el habitat de los peces de arrecife, basado en la distribución de las especies coros, es mucho mayor que lo que previamente se ha establecido; (2) que los arrecifes intermedios y los alejados de las costa, que se ha dicho tienen un solo conjunto faunístico en las Antillas, comprende dos faunas diferentes; (3) que la fauna de los arrecifes intermedios y lejanos de la costa se encuentra a diferentes profundidades y presenta diferente tolerancia térmica mínima; y (4) que el factor primordial que influencia los diferentes conjuntos faunísticos de arrecifes son las variaciones estacionales de los frentes fríos en aguas interiores, y la intrusión estacional de aguas frías fuera de la costa en la plataforma continental. Estos cuatro puntos se discuten basados en datos obtenidos en las investigaciones de los recursos.

INTRODUCTION

Major recreational and commercial fisheries for reef fish exist in the South

habitat, a determination of the biomass and productivity of the reef fauna based on the biology and ecology of the species, and a determination of the environmental factors causing population fluctuations.

With our present state of knowledge, some conclusions that have been reached about reef species and habitat are not acceptable to us. We demonstrate that the "live bottom" reef habitat comprises a large area of the continental shelf; that the reef fish fauna can be divided into three assemblages; that the warm stable temperature zone of the shelf occurs at intermediate depths; and that the most productive area of the shelf for commercial reef fish and a subtropical mollusk occurs within this warm stable temperature zone.

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The term "live bottom" was first coined by Cummins, Rivers, and Struhsaker (1962) to describe highly productive trawling areas of hard bottom from North Carolina to Florida. They defined live bottom as composed of the following animals and inert material: "Loggerhead sponge, generally present, small to large amounts; fire sponge, generally present, variable amounts; other sponge, always present, small amounts; coral, occasionally present, small amounts; rock, sometimes present, variable amounts; and shell, usually present."

The first major attempt to define the major faunal fish zones on the continental shelf in the South Atlantic Bight was made by Struhsaker (1969). He defined "live bottom habitat" as islands of broken relief on the shelf appearing to consist of rock outcrops heavily encrusted with sessile invertebrates such as sponges and sea fans. Struhsaker described this habitat as harboring subtropical and tropical fishes, with the most productive areas off Northeastern Florida and South Carolina at depths from 24-42 m (13 to 23 fm). He distinguished the live-bottom areas inshore near 18 m (10 fm) as having a less-rich invertebrate fauna and occupied largely by black sea bass and scup.

Estimation of the bottom reef habitat is difficult because of the vast area encompassed, the cost of sampling, and the state of technology. Huntsman and Manooch (1978) stated, "We do not know exactly how much live bottom exists in the South Atlantic Bight but it is relatively rare." They cite estimates of live bottom to be 3 to 10% of the continental shelf, and that any evaluation of potential production must recognize that only a minor portion of the shelf can sustain reef fishes.

MATERIALS AND METHODS

Investigations on habitat, faunal surveys, systematics, and productivity have been conducted by the National Marine Fisheries Service (NMFS) and predecessor agencies in the South Atlantic Bight for over 30 years. Extensive studies have been made by other federal agencies, state fishery agencies, universities, and private companies, who have greatly added to the knowledge of the area.

The term cold-water intrusion, as defined in this paper, is the displacement shoreward on the shelf of cold bottom water by any type of oceanographic condition.

A compilation was made of the hard bottom areas in the South Atlantic Bight from literature and interviews for the Bureau of Land Management, Blake Plateau Planning Unit, in conjunction with the proposed oil OCS lease sale No. 43. Charts depicting the areas of hard bottom were issued as visual Nos. 3N and 4N, in 1976.

The method we used to determine the areas of live bottom differed from conventional methods. We reviewed the station sheets from exploratory fishing cruises and determined the stations where reef species were taken in the catch. This indicated that sometimes during the trawls at these stations live bottom was encountered. Stations were not used when only a single

secondary associated reef species was caught, unless other organisms indicated live bottom. We only used plectognath fishes in our choice of stations, when accompanied by other reef species, because of our lack of knowledge of this group.

We examined 5,300 *Silver Bay* stations and found reef fish listed in 1,000 stations in the South Atlantic Bight. In addition where published station records of subtropical fishes existed for exploratory vessels other than the *Silver Bay* (e.g. *Combat),* these records were also plotted. Research vessels used in the South Atlantic Bight by NMFS personnel were the *Pelican, Combat, George M. Bowers, Silver Bay, Oregon, Oregon II,* and *Undaunted.*

The magnitude of error using this system of plotting live bottom from reef fish catches was believed to be minimal. The symbol used to plot a station on a chart covered 1.55 km (2½ miles). The maximum distance traveled on an average trawl tow was 2½ miles. The maximum possible error that could exist from location of capture would be 1.55 km (2½ miles).

A list of the primary and secondary reef fish species (Table 1), as defined by Starck (1968), was compiled for the shelf in the South Atlantic Bight. We realized that in compiling this list that species omissions would be made, that some misidentifications would occur, and that some literature would be missed. An attempt was made to eliminate species based only on juvenile specimens captured in summer or early fall. Tropical reef fishes that occur only north to Sebastian, Florida, listed and discussed by Herrema (1974) and Gilmore (1977), were not included in our list of reef species from the bight. Sources for the fish species listed are in the senior author's file.

We classified the resident fish fauna of the South Atlantic Bight on the basis of minimum temperature tolerances that we observed in the field or from literature: tropicals, no growth at 18°C, mortality 16°-18°C; subtropical, no growth at 15°C, mortality 13°-15°C; and warm-temperate, no growth at 10°C, mortality 8°-10°C.

The catch data used in the Productivity section of this paper were from four different sources: *Silver Bay* trawl station log from Cummins et al. (1962) was used to determine the number of stations by depth in which over 136 kg (300 lb) of commercial species were taken (Table 4); *Silver Bay* reports for Cruises 23, 30-32, 35, 37, 40, 48, 49, and 52, from which catches of over 45 kg (100 lb) of a commercial species or species groups by depth were extracted (Table 5); Commercial Fisheries Review for 1960-1967 from which were extracted the area and depths of calico scallop beds and commercial concentrations (Table 6); and unpublished Summary Logs of the Cape Canaveral Scallop Ground for 1969-1975, issued by the National Marine Fisheries Service from which were extracted the areas of heavy concentrations of calico scallops and depths observed using RUFAS (Remote Underwater Fishery Assessment System), thus eliminating bias that might occur with exploratory fishing (Table 7).

DISTRIBUTION OF REEF HABITAT

The distribution of reefs is dependent upon the extent and types of hard bottom. Continental Shelf Associates (1979) on contract to the Bureau of Land Management conducted a major study on two live bottom areas off

Table 1. Reef fish species of the South Atlantic Bight (Inshore reef species collected by G.C. Miller north of Cape Canaveral during calico scallop investigations indicated by an asterisk)

ORECTOLOBIDAE
Ginglymostoma cirratum
MURAENIDAE
Anarchias yoshiae
Gymnothorax hubbsi
G. funebris
G. moringa
*G. nigromarginatus**
*G. vicinus**
Muraena miliaris
M. retifera
CONGRIDAE
*Conger oceanicus**
Paraconger caudilimbatus
OPHICHTHIDAE
Ahlia egmontis
Letharcus velifer
Myrichthys acuminatus
Mystriophis intertinctus
*Ophichthus ocellatus**
SYNODONTIDAE
Synodus intermedius
S. saurus
S. synodus
*Trachinocephalus myops**
BATRACHOIDIDAE
Opsanus pardus?
*O. tau**
GOBIESOCIDAE
*Gobiesox strumosus**
ANTENNARIIDAE
*Antennarius ocellatus**
A. radiosus
A. scaber
OGCOCEPHALIDAE
Ogocephalus vespertillio
*O. spp**
OPHIDIIDAE
Lepophidium jeannae
Ophidion holbrooki
O. selenops
Otophidium omostigmum
HOLOCENTRIDAE
Adioryx bullisi
A. vexillarius
Corniger spinosus
Holocentrus ascensionis
H. rufus
Myripristis jacobus
Ostichthys trachypomus
Plectrypops retrospinis
AULOSTOMIDAE
Aulostomus maculatus
FISTULARIIDAE
Fistularia tabacaria
F. villosa
SYNGNATHIDAE
*Hippocampus erectus**
Syngnathus dunckeri
S. elucens
CENTROPOMIDAE
Centropomus undecimalis
SERRANIDAE
Alphestes afer
Anthias nicholsi
A. tenuis
*Centropristis ocyurus**
*C. philadelphica**
*C. striata**
Dermatolepis inermis
Diplectrum bivittatum
*D. formosum**
Epinephelus adscensionis
E. drummondhayi
E. flavolimbatus
E. fulvus
E. guttatus
E. itajara
E. morio
E. nigritus
E. niveatus
E. striatus
Hemanthias vivanus
Holanthias martinicensis
Hypoplectrus unicolor
Liopropoma eukrines
Mycteroperca bonaci
M. interstitialis
M. microlepis
M. phenax
M. venenosa
Paranthias furcifer
Pronotogrammus aureorubens
*Serraniculus pumilio**
Serranus annularis
S. baldwini
S. notospilus
S. phoebe
*S. subligarius**
S. tabacarius
GRAMMISTIDAE
Rypticus bistrispinus
R. maculatus

Table 1. *(continued)*

R. saponaceus

PRIACANTHIDAE
Cookeolus boops
*Priacanthus arenatus**
P. cruentatus
Pristigenys alta

APOGONIDAE
Apogon maculatus
*A. pseudomaculatus**
A. quadrisquamatus
Astrapogon alutus
A. stellatus
Phaeoptyx pigmentaria
P. conklini

BRANCHIOSTEGIDAE
Caulolatilus cyanops
C. chrysops
C. microps
Lopholatilus chamaeleonticeps
Malacanthus plumieri

RACHYCENTRIDAE
Rachycentron canadum

CARANGIDAE
Caranx crysos
C. latus
C. ruber
*Decapterus punctatus**
*Selar crumenophthalmus**
Seriola dumerili
S. rivoliana
S. zonata

EMMELICHTHYIDAE
Erythrocles monodi

LUTJANIDAE
Lutjanus analis
L. apodus
L. buccanella
*L. campechanus**
L. cyanopterus
L. griseus
L. jocu
L. synagris
L. vivanus
Ocyurus chrysurus
Pristipomoides aquilonaris
Rhomboplites aureorubens

POMADASYIDAE
Anisotremus virginicus
*Haemulon aurolineatum**
H. parrai
H. plumieri
H. striatum
*Orthopristis chrysoptera**

SPARIDAE
Archosargus probatocephalus
Calamus bajonado
C. calamus
C. leucosteus
C. nodosus
C. penna
C. proridens
Diplodus holbrooki
Lagodon rhomboides
*Pagrus pagrus**
Stenotomus aculeatus
S. caprinus
S. chrysops

SCIAENIDAE
Equetus lanceolatus
Pareques acuminatus?
*P. umbrosus**
P. sp (Black Bar)

MULLIDAE
*Mullus auratus**
Pseudupeneus maculatus
Upeneus parvus

KYPHOSIDAE
Kyphosus incisor
K. sectatrix

EPHIPPIDAE
*Chaetodipterus faber**

CHAETODONTIDAE
Chaetodon aya
C. capistratus
C. ocellatus
C. sedentarius
C. striatus

POMACANTHIDAE
Centropyge argi
Holacanthus bermudensis
H. bermudensis xx
H. ciliaris
H. ciliaris?
H. tricolor
Pomacanthus arcuatus
P. paru

POMACENTRIDAE
Abudefduf saxatilis
A. taurus
*Chromis enchrysurus**
C. insolatus
C. scotti
Eupomacentrus fuscus
E. leucostictus
E. partitus
E. planifrons
E. variabilis

Table 1. *(continued)*

LABRIDAE
- *Bodianus pulchellus*
- *B. rufus*
- *Clepticus parrai*
- *Decodon puellaris*
- *Doratonotus megalepis*
- *Halichoeres bathyphilus*
- *H. bivittatus*
- *H. caudalis**
- *H. garnoti*
- *H. maculipinna*
- *H. poeyi*
- *Hemipteronotus martinicensis*
- *H. novacula**
- *Lachnolaimus maximus*
- *Thalassoma bifasciatum*

SCARIDAE
- *Cryptotomus roseus*
- *Nicholsina usta*
- *Sparisoma radians*

SPHYRAENIDAE
- *Sphyraena barracuda*
- *S. borealis*
- *S. guachancho*

OPISTOGNATHIDAE
- *Opistognathus lonchurus*
- *O. maxillosus*

DACTYLOSCOPIDAE
- *Gillelus sp.*

CLINIIDAE
- *Starksia ocellata*

CHAENOPSIDAE
- *Emblemaria atlantica*

BLENNIIDAE
- *Blennius marmoreus**
- *Chasmodes saburrae*
- *Hypleurochilus geminatus**

CALLIONYMIDAE
- *Callionymus bairdi*

GOBIIDAE
- *Coryphopterus punctipectophorus*
- *Evermannichthys spongicola*
- *Gnatholepis thompsoni*
- *Gobiosoma ginsburgi**
- *G. xanthiprora*
- *Ioglossus calliurus*
- *Lythrypnus nesiotes*
- *L. spilus*
- *L. sp.*
- *Risor ruber*

ACANTHURIDAE
- *Acanthurus bahianus*
- *A. chirurgus*
- *A. coeruleus*

SCORPAENIDAE
- *Helicolenus dactylopterus*
- *Pontinus nematophthalmus*
- *P. helena*
- *P. longispinis*
- *Scorpaena agassizi*
- *S. albifimbria*
- *S. brasiliensis**
- *S. calcarata**
- *S. dispar*
- *S. isthmensis*
- *S. plumieri*
- *Scorpaenodes tredecimspinosus*

TRIGLIDAE
- *Bellalor militaris**
- *Prionotus evolans*
- *P. ophryas**
- *P. roseus**
- *P. salmonicolor**

DACTYLOPTERIDAE
- *Dactylopterus volitans*

BOTHIDAE
- *Ancylopsetta quadrocellata*
- *Bothus ocellatus**
- *B. robinsi**
- *Cylopsetta fimbriata*
- *Etropus rimosus**
- *Syacium micrurum*
- *S. papillosum**

BALISTIDAE
- *Aluterus heudeloti*
- *A. monoceros*
- *A. schoefi**
- *A. scriptus*
- *Balistes capriscus**
- *B. vetula*

MONACANTHIDAE
- *Stephanolepis ciliatus**
- *S. hispidus**

OSTRACIIDAE
- *Lactophrys bicaudalis*
- *L. trigonus*
- *Acanthostracion polygonius*
- *A. quadricornis*

TETRAODONTIDAE
- *Canthigaster rostrata*
- *Sphoeroides dorsalis*
- *S. pachygaster*
- *S. spengleri**

DIODONTIDAE
- *Chilomycterus antillarum*
- *C. schoepfi*
- *Diodon holocanthus*
- *D. hystrix*

Georgia and South Carolina. They found three different faunal assemblages off South Carolina. Assemblage A, on soft bottom not underlain with hard bottom; Assemblage B, on emergent hard bottom, only slightly elevated, dominated by sponges and gorgonians; and Assemblage C, on slightly rippled sand bottom, apparently underlain by hard substrate dominated by an anthozoan, a few sponges, and occasionally colonies of encrustory polychaetes. They stated Assemblages B and C tend to mix together in areas without emergent rock but contained patches of what appeared to be cobbles and shells, which provide substrate for attachment; and that this area contained the largest numbers of species and greatest biomass; and that hydroids, bryozoans, and ascidians were also frequently observed.

The Continental Shelf Associates' (1979) findings are important in that primary and secondary reef species are found on flat, non-discernible, or slightly emerging hard bottom supporting anthozoans, sponges, hydroids, ascidians, gorgonians, and polychaetes, and are not dependent on elevated reefs.

Live bottom habitat was plotted from the *Silver Bay* and *Combat* station sheets from which reef species were listed (Fig. 1). Live bottom occupied a very large area of the South Atlantic Bight. A close similarity is seen between Figure 1 and hard bottom areas compiled in the BLM charts previously cited. Estimates of reef fish biomass and production should include areas of flat hard bottom as well as elevated bottom.

REEF FISH FAUNA, SOUTH ATLANTIC BIGHT

The reef fish fauna of the South Atlantic Bight can be divided into the estuarine and inshore reefs usually less than 18 m (10 fm); the intermediate reefs between 18-55 m (10-30 fm); and the offshore reefs 55-183 m (30-100 fm). The inshore area between Jacksonville and Miami is a transitional zone between temperate and tropical species.

The number of reef fish species occurring in the South Atlantic Bight (Table 1) is comparable in number to the reefs in the eastern Gulf of Mexico (Smith, 1976).

Inshore Reefs

The warm-temperate fish species occurring on the inshore reefs north of Sebastian Inlet, Florida, are inadequately listed in the literature. The inshore reefs have a pauperized fauna, consisting primarily of secondary reef species, that have a broad distribution across the shelf.

The fishes of the inshore live bottom were studied by the senior author during a calico scallop biology study on the Cape Canaveral grounds (G.C. Miller, manuscript in prep.). Two sampling stations were established north of Cape Canaveral and were named Buoy 1 and Buoy 2 (Allen, 1979). Buoy 1 was located inshore in 18 m (10 fm), immediately south of an elevated reef. Buoy 2 occurred offshore east of Buoy 1, in 22 m (12 fm), adjacent to a calico scallop bed live bottom community. The fishes captured were taken in trawls, and entrapped in cages holding scallops, at the two locations. A

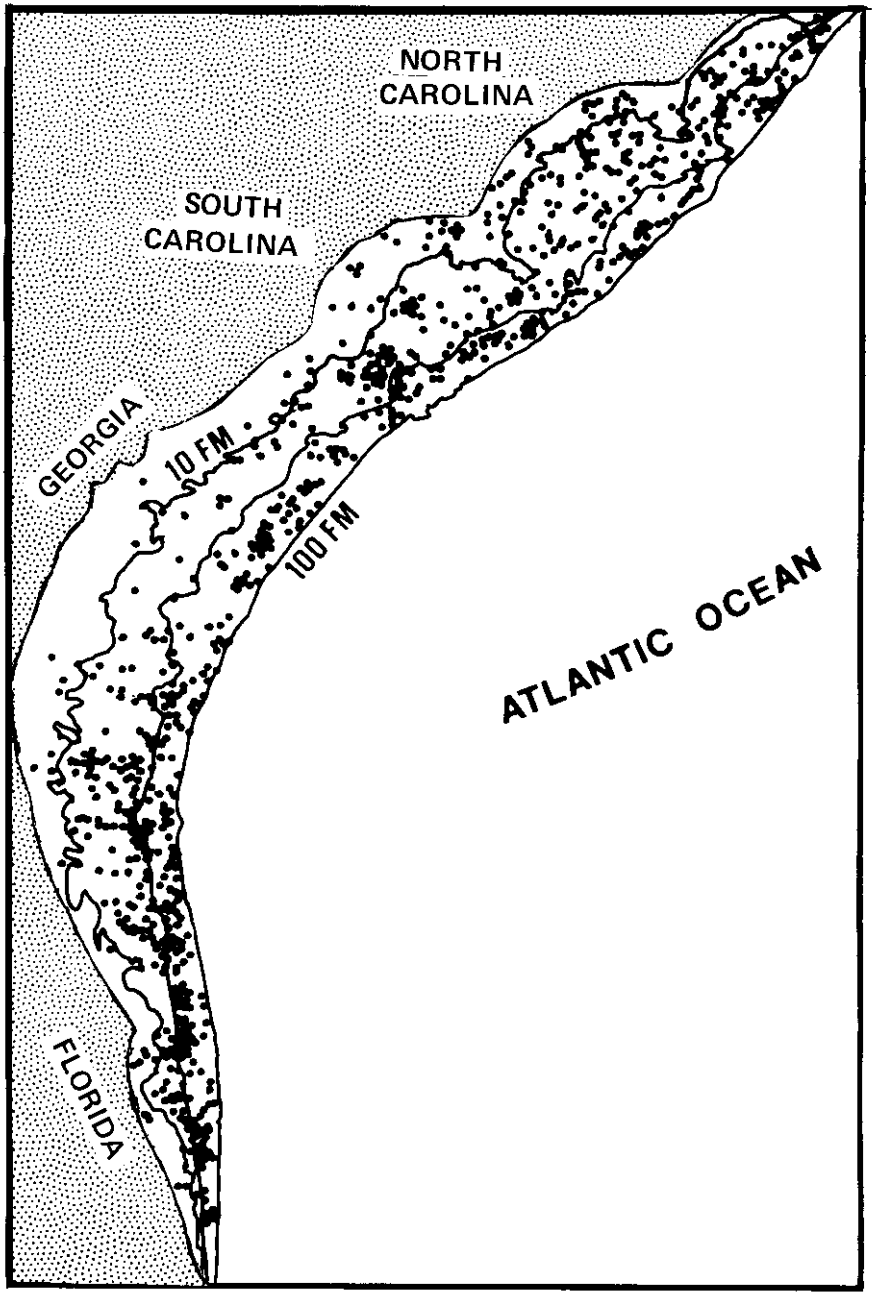

Figure 1. Distribution of live bottom habitat in the South Atlantic Bight from reef fishes collected in 1,000 *Silver Bay* and *Combat* stations.

majority of the fishes captured, indicated by an asterisk in Table 1, were primary and secondary reef species. The fishes were primarily the young of the large-size species and the young and adults of the small-size species. Noticeably lacking in the catch were the mangrove snapper, *Lutjanus griseus*, and the sheepshead, *Archosargus probatocephus*. Of the species taken, *Blennius marmoreus* and *Hypleurochilus geminatus* have been considered rare enough in North Carolina to be considered potentially endangered (Schwartz et al., 1977).

Intermediate Reefs

The intermediate reefs harbor distinct groups of species: (1) species with warm-temperate tolerances, whose distributions extend across the shelf; (2) species with warm-temperate tolerances, that occur at depths greater than 55 m (30 fms) and may seasonally move into the intermediate reefs; and (3) species with subtropical tolerances, which are confined to the intermediate reef or may seasonally move to the inshore or offshore reefs. The flat, sponge-gorgonian hard bottom provides a niche for species long classified as tropicals.

Five species were chosen as indicators of the subtropical tolerant fauna on the intermediate reefs: *Chaetodon ocellatus, C. sedentarius, Holacanthus bermudensis, Equetus lanceolatus,* and *Lachnolaimus maximus.* Other subtropical fishes taken on these reefs are *Ocyurus chrysurus, Haemulon plumieri, Mullus auratus, Pseudupeneus maculatus, Chaetodon striatus, Holocanthus tricolor, Holocentrus ascensionis,* and *Apogon pseudomaculatus.*

The distribution on the shelf of the intermediate reef indicator species was compiled from 193 *Silver Bay* station records and plotted in 8 m (5 fm) intervals (Table 2). It can be seen that the center of distribution of the species is in 33-41 m (18-22 fm), and the species were collected in 24-59 m (13-32 fm), in 84% of the stations.

This indicator species distribution is not erroneous due to selectively sampling certain depths while exploratory fishing. We found less than 21% overlap in depth between the intermediate and offshore reef indicator species.

Offshore Reefs

The offshore reef fishes are composed of three different assemblages: (1) warm-temperate tolerant species found distributed across the shelf; (2) subtropical tolerant species that can invade the offshore reefs seasonally or areas not adversely affected by intrusions; and (3) warm-temperate tolerant species occurring primarily on the outer reefs (greater than 55 m, 30 fm) that can invade intermediate reefs. The species, generally only found in water deeper than 55 m (30 fm), can be classified as follows: (1) tropical eurybathic stenothermic emergent warm-temperate tolerant species (e.g., *Lutjanus buccanella,* and *L. vivanus*); (2) geminate warm-temperate tolerant species derived from tropical eurybathic emergent warm-temperate tolerant species [*Chaetodon aya* from *C. guyanensis,* and *Peristedion gracile* from *P.* sp. (Bristly)]; and (3) tropical eurythermic warm-temperate tolerant species [*Pareques* sp. (Black Bar)].

Table 2. Distribution of indicator reef fish species *(Chaetodon ocellatus, C. sedentarius, Holacanthus bermudensis, Equetus lanceolatus, Lachnolaimus maximus)* of intermediate reefs, collected from 193 *SILVER BAY* stations in South Atlantic Bight, grouped in 8 m (5 fm) depth intervals

Depth m	Depth fm	Number Station Species Collected	% Total Stations Species Collected
5-14	3- 7	4	2.1
15-23	8-12	3	1.6
24-32	13-17	46	23.8
33-41	18-22	86	44.6
42-50	23-27	16	8.2
51-59	28-32	14	7.3
60-68	33-37	17	8.8
69-78	38-42	2	1.0
79-87	43-47	2	1.0
88-95	48-52	3	1.5
Total		193	99.9

A distinct fauna occurs on the outer shelf at depths greater than 55 m (30 fm). Six species chosen as indicators of the offshore reef fauna were *Chaetodon aya, Pareques* sp. (Black Bar), *Hemanthias vivanus, Corniger spinosus, Holocentrus bullisi,* and *Antennarius radiosus.* Other species that were taken primarily offshore were *Epinephelus drummondhayi, E. flavolimbatus, Holanthias martinicensis, Lutjanus buccanella, L. vivanus, Pristipomoides aquilionaris, Ostichthys trachypomus, Decodon puellaris, Cookeolus boops,* and scorpaeniids.

When depth distributions of these species were examined with the depths of capture only 21% of the stations of capture occurred at depths less than 55 m (30 fm) (Table 3).

TEMPERATURE EFFECTS ON FISH DISTRIBUTION

Temperature is a primary factor in the distribution of species in the South Atlantic Bight. Seasonal cooling of inshore water by cold fronts limits the northern distribution of tropical species along the coast north of Sebastian, Florida. Gilmore, Bullock, and Berry (1978) reported that cold fronts affect tropical species in the estuaries and that reef fish show stress and mortality on reefs as deep as 40 m (22 fm) off western Florida and 3-7 m (1.6-3.8 fm) off Atlantic beaches. Gilmore (1977) speculated that tropicals and subtropicals could exist near shore only as far north as Sebastian before they are forced to submerge to deeper, warmer water.

Intrusions of cold water on the outer shelf are not uncommon in the South Atlantic Bight. These intrusions in Florida have been reported in the

Table 3. Distribution of indicator reef fish species [*Chaetodon aya, Pareques* (Black Bar), *Hemanthias vivanus, Corniger spinosus, Holocentrus bullisi, Antennarius radiosus*] of offshore reefs, collected from 63 *Silver Bay* stations in South Atlantic Bight, grouped in 17-18 m (10 fm) depth intervals

Depth m	Depth fm	Number Station Species Collected	% Total Stations Species Collected
18- 36	10-19	2	3.2
37- 54	20-29	11	17.5
55- 72	30-39	19	30.2
73- 90	40-49	15	23.8
91-109	50-59	11	17.5
110-127	60-69	3	4.8
128-144	70-79	2	3.2
Total		63	100.2

literature since 1883 (Pierce, 1883, 1884) with many reports of reef fish kills due to them. Upwelling of slope water on the shelf off St. Augustine was reported to regularly occur during the summer by Taylor and Stewart (1959). Walford and Wicklund (1968) showed cold water invading the shelf in many areas.

An environmental study by Leming (1979) was conducted off Cape Canaveral in conjunction with the calico scallop biology program of the Miami Laboratory. The senior author (Miller) from these studies (paper presented at the American Society of Ichthyologists and Herpetologists annual meeting, June 19, 1972) showed the following: the inshore waters off Cape Canaveral were seasonally cooled below 15° to 18 m (10 fm) deep, whereas the offshore waters were seasonally cooled below 15°C shoreward to 55 m (30 fm) by cold water intrusions; the fauna between 18-55 m (10-30 fm) was composed of warm-temperate and subtropical species; the subtropical reef fish extended in a narrow productive zone, 33-40 m (18-22 fm), from Florida to North Carolina; on the northern and southern ends of the bight the species occurred in shallower water; tropical tolerant species (minimum tolerance 16°C-18°C) could not live, except seasonally, much farther north than Fort Pierce; and past 55 m (30 fm) in depth temperature deviations were greater in the summer and less stable than inshore.

The temperatures of the outer shelf have been reported more stable than those inshore due to the proximity of the outer shelf to the Florida Current and Gulf Stream. This is not true. cold water intrusions cause the outer shelf bottom temperature to strongly deviate with the 15°C isotherm extending inshore to 55 m (30 fm), and the 10°C isotherm inshore to 84 m (46 fm) (Leming, 1979; Avent et al., 1977).

The question "Why were these subtropicals confined to a productive, narrow zone, intermediate on the shelf if intrusions of cold water did not

Table 4. Catch of commerical species exceeding 136 kg (300 lb) from *SILVER BAY* trawl stations in South Atlantic Bight, grouped in 9 m (5 fm) depth intervals (extracted from Cummins Jr., Rivers, and Struhsaker, 1962, Sep. No. 661)

Depth m	Interval fm	Number Station Catch Over 136 kg	% Total Station Catch Over 136 kg	Weight Catch lb	Weight Catch kg	% Total Weight Catch
5-14	3- 7	1	1.1	600	272	0.5
15-23	8-12	3	3.2	3,669	1,664	3.3
24-32	13-17	18	19.4	18,208	8,259	16.2
33-41	18-22	56	60.1	76,899	34,881	68.5
42-50	23-27	6	6.5	4,218	1,913	3.8
51-59	28-32	4	4.3	5,800	2,630	5.2
60-68	33-37	2	2.2	1,713	777	1.5
69-78	38-42	2	2.2	635	288	0.6
79-87	43-47	0	0.0	0	0	0.0
88-95	48-52	1	1.1	558	253	0.5
Total		93	100.1	112,300	50,937	100.1

occur along the Georgia, South Carolina, and North Carolina coasts?" was answered by Mathews and Pshuk (1977) who showed that inshore cooling and cold-water intrusions did occur on the outer shelf in February-March in the South Atlantic Bight and did confine the warmest temperatures intermediate on the shelf (Fig. 2).

In an area where the shelf is narrow and with a strong current adjacent, are the offshore cold water intrusions more influential on the tropical fauna than seasonal cooling inshore? This question was answered by Herrema's (1974) and Gilmore's (1977) studies in southern Florida, which showed that the tropical reef fish are confined to a very narrow zone adjacent to the shore. Similar conditions affect the tropical fauna on Campeche Bank (Miller and Kent, 1972).

PRODUCTIVITY

The most stable area of the shelf occurs between 26-51 m (14-28 fm) with the center of distribution of subtropical reef fishes in 33-40 m (18-22 fm). The following data show that this zone supports the major productivity of commercial reef fishes and a commercial subtropical mollusk.

Table 4 shows that 80% of the stations with catches over 136 kg (300 lb) and 85% of the total catch weight occurred at depths from 24-41 m (13-22 fm); and nearly 70% of the total catch weight was taken in 33-41 m (18-22 fm).

The largest catch weight by species or species group occurred at depths from 31-45 m (17-24 fm) (Table 5). At these depths 100% of the hogfish weight was caught, 74% of the groupers, 74% of the porgies, 58% of the scups, 52% of the snappers, 35% of the black sea bass, and 25% of the grunts. The even distribution of the catch of black sea bass by depth is due to its broad

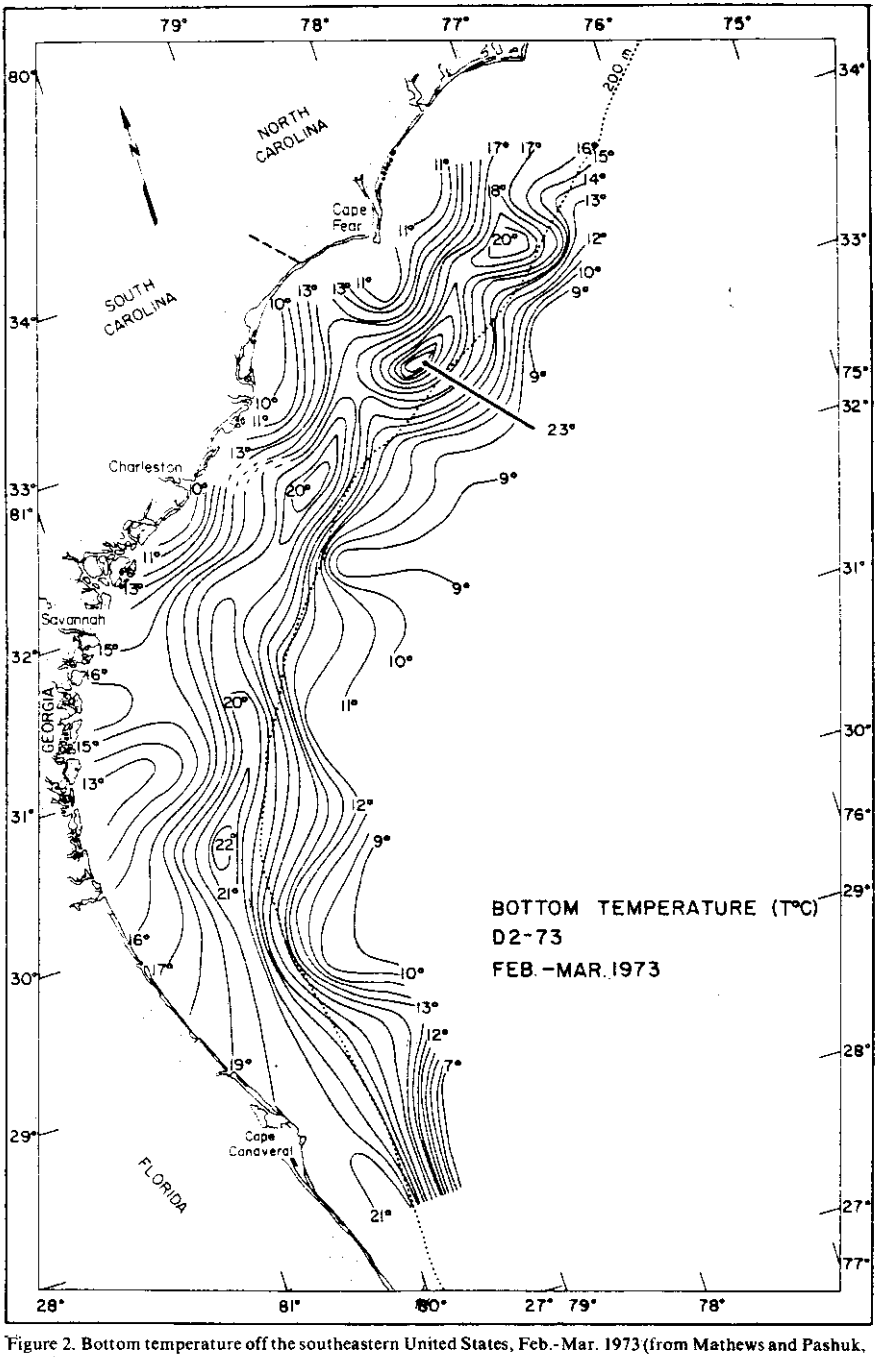

Figure 2. Bottom temperature off the southeastern United States, Feb.-Mar. 1973 (from Mathews and Pashuk, 1977, Fig. 28).

Table 5. Catch of a commerical species exceeding 45 kg (100 lb), from *SILVER BAY* stations in South Atlantic Bight listed by species or species group by depth (extracted from *SILVER BAY* Cruise Reports)

Depth m	Depth fm	No. Sta.	Hogfish kg	Snapper kg	Grouper kg
13-21	7-11	4		298	
22-30	12-16	20		25,258	593
31-45	17-24	54	1,274	32,229	11,336
46-54	25-29	9		2,857	2,703
55-82	30-34	13		1,850	750
Total		100	1,274	62,492	15,382
			100*	52*	74*

*Percentage of total kg of a species or species group caught in 31-45 m (17-24 fm).

Table 5. *(Continued)*

Black Sea Bass kg	Porgy kg	Scup kg	Grunts kg
661		7,385	661
573	70	16,596	6,739
1,102	34,546	35,928	2,870
485	723	2,425	882
309	11,583		132
3,130	46,922	62,334	11,284
35*	74*	58*	25*

distribution across the shelf, whereas the two species of grunts (*H. plumieri* and *H. aurolineatum)* are found predominately in the open-shelf zone.

The major scallop beds and concentrations from 1960-1967 were found at depths from 26-42 m (14-23 fm) and from 46-49 m (25-27 fm) (Table 6).

Table 7 shows that on the Cape Canaveral scallop grounds 1969-1975, the heavy concentrations of scallops were observed at depths from 26-49 m (14-27 fm) with the largest numbers of concentrations occurring from 33-42 m (18-23 fm).

CONCLUSIONS

The reef fishes found in the South Atlantic Bight are primarily of tropical origin. Tropical tolerant species can exist as residents only on shallow inshore reefs or in the estuary along the southeast Florida coast. The resident reef species north of Sebastian, Florida, are warm-temperate or subtropical tolerant. The subtropical tolerant species occur in the intermediate open-shelf zone from 18-55 m (10-30 fm) with their center of distribution from 33-40 m (18-22 fm).

Table 6. Major calico scallop beds or concentrations by depth from exploratory fishing cruises in South Atlantic Bight (extracted from Commercial Fisheries Review, 1960-1967). Asterisk indicates SB = R/V *SILVER BAY* and Ore = R/V *OREGON*

Cruise	Area	Depth m	fm	Year	Commercial Fisheries Review
SB* 22	Core Bank, NC	29-35	16-19	1960	22(5):29-31
SB 23	Daytona-Ft.Pierce, FL	27-46	15-25	1960	22(7):41-43
SB 25	Core Bank, NC	37-37	20-21	1960	22(10):42-43
SB 28	Ft. Pierce, FL	33	18	1961	23(4):32
SB 29	Core Bank, NC	46	21-25	1961	23(5):24-25
SB 31	SSE of Cape Canaveral, Fl	37	20	1961	23(10):28-29
SB 35	Core Bank, NC,	31-37	17-20	1962	24(2):39-40
SB 35	Daytona Beach, FL	24-29	13-16	1962	24(2):39-40
SB 39	Cape Lookout-Cape Hatteras, NC	35	19	1962	24(8):38-39
SB 42	Bethel Shoals, FL-St. Marys, GA	26-37	14-20	1963	25(1):53-54
SB 47	Cape Canaveral, FL	46	25	1963	26(6):41
SB 55	New Smyrna Beach, FL	29	16	1964	26(6):27-29
SB 55	E of Cape Canaveral, FL	48	26	1964	26(6):27-29
SB 55	SE of Bethel Shoals, FL	46	25	1964	26(6):27-29
SB 55	E of St. Lucie Inlet, FL	37	20	1964	26(6):27-29
Ore 103	Cape Canaveral-Mayport, FL	49-60	27-33	1965	27(11):34-35
Ore 121	E of New Smyrna Beach, FL	46-49	25-27	1967	29(11):22-24
Ore 121	Hetzel Shoals-Melbourne, FL	38-42	21-23	1967	29(11):22-24
Ore 121	NE of Bethel Shoals, FL	35-38	19-21	1967	29(11):22-24
Ore 122	New Smyrna Beach—Mayport, FL	46-49	25-27	1967	29(12):25-26
Ore 123	E of New Smyrna Beach, FL	42-49	23-27	1967	29(12):27
Ore 123	E of Cape Canaveral, FL	40-48	22-26	1967	29(12):27

The reef fish habitat consists not only of elevated reefs, but flat hard bottom which support live bottom communities. Distribution of reef fish in the exploratory catches showed a large area of the shelf had live bottom.

Seasonal cooling inshore and intrusions of cold water from offshore confine the subtropical tolerant fauna to an intermediate zone on the shelf with warmer, more stable bottom temperatures. The most stable warm temperature area on the shelf occurs in the open shelf zone in 33-40 m (18-22 fm) depth.

The most productive area of the shelf for commercial reef fish and for a commercial subtropical mollusk occurred in the open shelf zone at the same depths, 33-40 m (18-22 fm), as the most stable warm temperatures.

We did not attempt to estimate the magnitude occupied by the reef fish

Table 7. Heavy concentration of calico scallops from Cape Canaveral grounds, 1969-1975 (Summary Log lacking in 1973), by transect and depth (extracted from Summary Log of scallop locations with predicted catch rates of Cape Canaveral grounds, National Marine Fisheries Service, Brunswick, and Miami Laboratories)

Loran Transect (3H7 or 3LI)	Season						
	Fall 1969	Spring 1970	Summer 1970	Summer 1971	Spring 1972	Summer 1974	Summer 1975
	Depth in meters						
1500				35-38	33,48		
1600				31-37	33		
1700				38-40			
1800				38-42		38-40	
1900							40-42
2000			40	37-42			
2100	40-42	40	38-42	44			
2200	33	38-40		40-44			
2300		42-46	49-53				49
2400		42-44	38-40				
2500	33-35	35,42		31-33			
2600	26-31						
2700	27-31						
2800	31						

habitat in the South Atlantic Bight, because we did not have the resources available to investigate all historical records. We have shown that large numbers of commercial reef fish are taken on relatively flat sponge-gorgonian bottom, that tentative conclusion can be made and that a wealth of material exists for a statistical analysis and a reliable estimate of the reef fish habitat in the bight.

LITERATURE CITED

Allen, D.M.
1979. Biological aspects of the calico scallop, *Argopecten gibbus*, determined by spat monitoring. Nautilus 93: 107-119.

Avent, R.M., M.E. King, and R.H. Gore
1977. Topographic and faunal studies of shelf-edge prominences off the central eastern Florida coast. Int. Revue ges Hydrobiol. 62: 185-208.

Continental Shelf Associates
1979. South Atlantic hard bottom study. Prepared for Bureau of Land Management, U.S. Dept. Commerce, Nat. Tech. Inf. Serv. PB-300821. 356 pp.

Cummins, R., Jr., J.B. Rivers, and P. Struhsaker
1962. Snapper trawling explorations along the southeastern coast of the United States. Comm. Fish. Rev. 24(12). 7 pp. Sep. No. 661.

Gilmore, R.G., Jr.
1977. Fishes of the Indian River lagoon and adjacent waters, Florida. Bull. Fla. Sta. Mus. Biol. Sci. 22: 101-147.

———————, L.H. Bullock, and F.H. Berry
1978. Hypothermal mortality in marine fishes of South-Central Florida, January, 1977. N.E. Gulf Sci. 2: 77-97.

Herrema, D.J.
1974. Marine and brackish water fishes of southern Palm Beach and northern Broward counties. Fla. Atl. Univ., M.Sc. thesis. 257 pp.

Huntsman, G.R. and C.S. Manooch III
1978. Coastal pelagic and reef fishes in the South Atlantic Bight. Mar. Rec. Fish. No. 3. Pages 97-106 *in* H. Clepper, ed. Proc. 2nd Ann. Mar. Rec. Fish. Symp., Sport Fish. Instit., Wash. D.C. 176 pp.

Leming. T.D.
1979. Observations of temperature, current, and wind variations off the central eastern coast of Florida during 1970 and 1971. NOAA Tech. Mem. NMFS-SEFC-6. 171 pp.

Mathews, T.D. and O. Pashuk
1977. A description of oceanographic conditions off the southeastern United States during 1973. S. Carolina Mar. Res. Center Tech. Rept. 19. 105 pp.

Miller, G.C. and D.M. Kent
1972. Redescription of *Prionotus beani* (Pisces, Triglidae). Quart. Jour. Florida Acad. Sci. 34, 1971: 223-242.

Pierce, H.D.
1883. The spawning of bluefish. An opinion of the cause of mortality in the Gulf of Mexico. Bull. U.S. Fish Comm. 3:332.

———————
1884. Notes on the bluefish, Mortality of Florida fishes, etc. Bull. U.S. Fish. Comm. 4: 263-266.

Schwartz, F.J., W.W. Hassler, J.W. Reintjes, and M.W. Street
1977. Marine Fishes. Pages 250-264 *in* J.E. Cooper, S. Robinson, and J.B. Funderberg, eds. Dangered and threatened plants and animals of North Carolina. N. Carolina Sta. Mus. Nat. Hist., Raleigh, Symposium Proc.

Smith, G.B.
1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Fla. Dept. Nat. Resources, Fla. Mar. Res. Publ. 19. 78 pp.

Starck, W.A., II
1968. A list of fishes of Alligator Reef, Florida with comments on the nature of the Florida reef fish fauna. Undersea Biol. 1: 5-40.

Struhsaker, P.
1969. Demersal fish resources; composition, distribution, and commercial potential of the continental shelf stocks off southeastern United States. Bur. Comm. Fish. U.S., Fish. Indust. Res. 4: 261-300.

Taylor, C.B. and H.B. Stewart, Jr.
1959. Summer upwelling along the east of Florida. J. Geophys. Res. 64: 33-40.

Walford, L.A. and R.I. Wicklund
1968. Serial atlas of the marine environment. Monthly sea temperature structure from the Florida Keys to Cape Cod. Am.Geog. Soc. Folio 15.